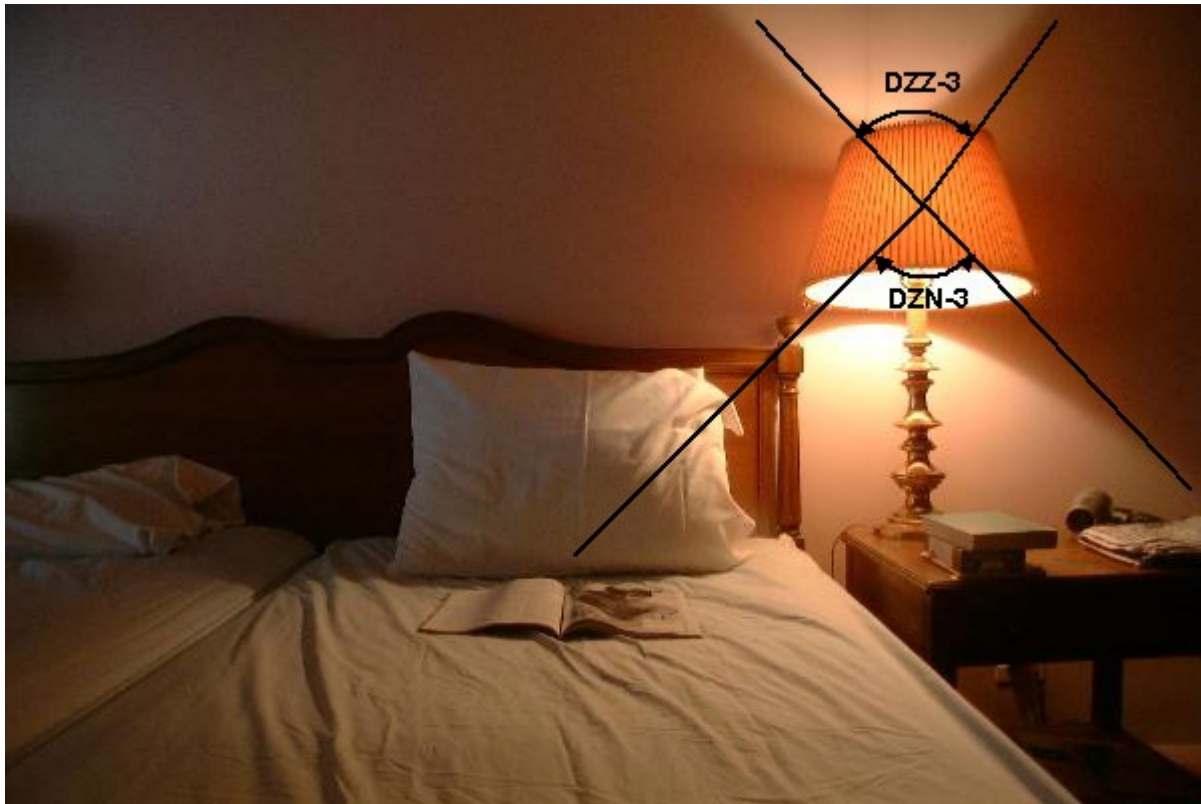


## Comments on Energy Star Program Requirements for Integral Lamps-Draft 3

Draft 3<sup>1</sup> of the Energy Star program requirements for LED integral Lamps has all but removed any requirements on the distribution of light produced by omnidirectional lamps (light bulbs). Unacceptably, “omnidirectional” LED bulbs with the Energy Star imprimatur will not need to be omnidirectional at all in order to qualify as omnidirectional. The photograph shows a typical application of an omnidirectional light bulb being used in a table lamp on a nightstand. According to draft 3 it is permissible to have zero direct light emitted into the zenith zone labeled DZZ-3 and zero direct light emitted into the nadir zone labeled DZN-3. There would be no requirement for bright halos of light emitted from the top of the lamp shade (around zenith) and the bottom of the shade (around nadir) that provide the bulk of the illumination provided by lamps.



Whereas the draft 1 required uniformity of +/- 10% in the polar angle range of 0°-150° and draft 2 loosened the uniformity requirement to a stipulation of +/-20% which only needed to be met in the polar range 0°-135°, now, in response to the suggestion of a foreign lamp

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<sup>1</sup> Located at DOE contractor website <http://drintl.com/HtmlEmail/SSL/IntegralLampsDRAFT3-18Sep09.pdf> & [http://www.energystar.gov/index.cfm?c=new\\_specs.integral\\_leds](http://www.energystar.gov/index.cfm?c=new_specs.integral_leds)

manufacturer that misunderstood a European Community regulation, the DOE has amended draft-3 and all but eliminated any requirement. The only requirement of draft 3 is that at least 20% of the light emitted by the light bulb be emitted anywhere in the polar angular range from 90° to 180°<sup>2</sup>. All types of wildly uncontrolled light distributions will meet the DOE's Energy Star Requirements. All of a lamp's light flux could be concentrated in a narrow annular ring at co-latitude 110° and the lamp would qualify as "omnidirectional" under the proposed standard. There is basically no requirement for optical engineering in the design of omnidirectional light bulbs. Any inexperienced hack engineer could slap together a design for sale to unwitting consumers in big box stores.

### The DOE Intends to Adapt a European "Legal Definition" as a U.S. "Technical Standard"

The European Commission (EC) regulation 244/2009<sup>3</sup> is written in a legalistic manner, as is to be expected of such a document. In the EC document a legal definition is set out for demarcating different types of lamps so that different requirements can be stipulated for one type while making clear such requirements do not apply to another type. The legal definitions in EC 244/2009 are:

*"5. 'directional lamp' means a lamp having at least 80 % light output within a solid angle of  $\pi$  sr (corresponding to a cone with angle of 120°);*

*6. 'non-directional lamp' means a lamp that is not a directional lamp;"*

Establishing definitions is a common practice in composing legal documents. This definition was formulated to cover a decidedly broad range of 'non-directional' lamps<sup>4</sup> in order to insure a large impact on energy usage. The legal definition adequately serves its intended limited purpose of demarcating two types of lamps but it was never intended to establish technical standards for the light distributions of omnidirectional lamps. The EC definition covers what is being 'banned' and what must be replaced with more efficient alternatives. It was never intended to stipulate what is an ideal distribution of even what is a merely good distribution. **The DOE is essentially adapting an EC definition for a purpose that is opposite to the intended**

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<sup>2</sup> The other "requirement" that no more than 80% of the light be emitted in the polar angle range of 0° to 60° is entirely superfluous because meeting the requirement for 90° to 180° guarantees that the requirement for 0° to 60° will be met, i.e., 100% - 20% = 80%.

<sup>3</sup> See <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:076:0003:0016:EN:PDF>

<sup>4</sup> For example it can be assumed that the EC's intent was to ban incandescent lamps with poorer light distributions hence the EC would not restrict the definition to lamps with better distributions.

**purpose.** The EC's purpose was an expansive definition to sweep in a large swath of lamp types for phase out. On the other hand the Energy Star standards are supposed to define high performance products.

The party that suggested that the DOE adapt the EC "legal definition" as a "technical standard" was Neo Neon Lighting International<sup>5</sup>. In making the suggestion Neo Neon revealed a lack of basic mathematical knowledge that is prerequisite to competent illumination engineering and thus should raised doubts with the DOE. Neo Neon erroneously equated the 120° ( $\pi$  steradian) cone mentioned in the EC "legal definition" to a 0° to 120° polar angle range which, in fact, corresponds to a solid angle of  $3\pi$  steradian, and suggested that because 0° to 120° is close to the 0° to 135° over which uniformity was specified in the DOE's draft-2, that the DOE should just adapt the EC "legal definition" as its "technical standard". **Despite the clear error and clear inappropriateness the DOE acceded to Neo Neon's request.**

The U.S. DOE has gone ahead and adapted this "legal definition" for use in its "technical standard" i.e., draft-3. The DOE intended to augment this "technical standard" by adding the requirement that at least 20% of the light emitted by the light bulb will fall in the 90° to 180° angle range. Unwittingly (apparently), by making this addition the DOE has rendered the requirement adapted from the EC regulations superfluous. The "challenge" of identifying which requirement is superfluous can be presented as give-away intelligence test:

Question 1: Which one of the two DOE's draft-3 requirements for omnidirectional LED light bulbs is practically speaking superfluous:

- A) Products shall have less than 80% of total flux in the 0° to 60° zone
- B) Products shall have at least 20% of total flux above 90°

Hint,Hint:  $20\%+80\%=100\%$

Answer: The answer is A, because if a product meets B by having at least 20% of total flux above 90° it cannot have more than 80% of flux in the 0° to 60° range<sup>6</sup>.

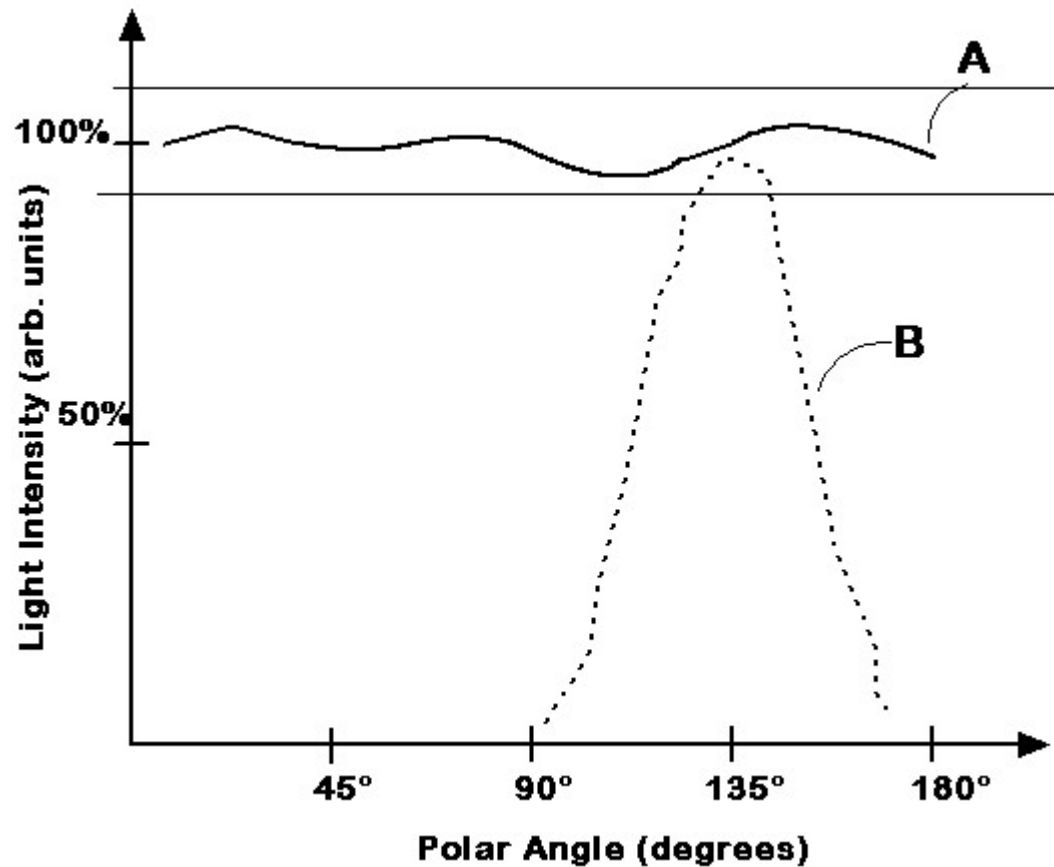
As a result, the only real requirement is B, and this is an extremely loose standard that allows for lamps with all kinds of wildly uncontrolled light distributions to qualify as omnidirectional. No light is required in 0° to 60° or for that matter in 0° to 90°.

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<sup>5</sup> See [http://www.energystar.gov/index.cfm?c=new\\_specs.integral\\_leds](http://www.energystar.gov/index.cfm?c=new_specs.integral_leds) Neo Neon International Comments 1

<sup>6</sup> The only theoretical case excluded by A but not by B is a lamp that produces exactly 80% in the 0° to 60° zone, with zero tolerance. Zero tolerance is not obtainable in the real world.

Example of Highly **Non**-Omnidirectional Light Distribution That Passes as  
“Omnidirectional” under the DOE’s Draft 3 Standard



The graph above shows plots (A & B) of light intensity versus polar angle for the light emitted by LED light bulbs. Plot A is for a good omnidirectional lamp. The lamp represented by plot A emits light fairly evenly from 0° to 180° (in all directions=omnidirectionally). The lamp represented by plot B does **not** provide omnidirectional illumination. The illumination of B is limited to the polar angle range from 90° to 180°. The illumination of B is also very uneven (non-uniform). It is strongly peaked at 135°. Yet contrary to reason, the plot B distribution qualifies as “omnidirectional” under the DOE’s draft-3 *Energy Star* requirements.

Comparison of Energy Star Requirements with L-Prize Requirements

It is instructive to compare the proposed draft-3 Energy Star distribution requirements for omnidirectional lamps with the L-Prize requirements<sup>7</sup> for omnidirectional lamps. The L-Prize criteria reflects the DOE's own thinking on what a very good distribution is for omnidirectional LED light bulbs. The L-Prize criteria stipulates uniformity of +/-10% over the polar angle range of 0°-150°. This corresponds to the draft-1<sup>8</sup> Energy Star requirements. Draft-2 slackened this to +/-20% over the polar angle range of 0°-135°. Now draft-3 is basically abandoning any uniformity requirement.

### Conflict with Congressional Intent of "Energy Independence and Security Act of 2007"

The "omnidirectional" category of draft 3 includes A-type lamps which includes LED based "general service lamps" which are covered by the **"Energy Independence and Security Act of 2007"**<sup>9</sup>. General service lamps consume a significant fraction of electricity used for illumination. The uniformity standard in draft 3 is so weak that it undermines provisions of the **"Energy Independence and Security Act of 2007"** that deal with LED general service lamps. "Omnidirectional" LED lamps will not be suitable for use as "general service lamps" if their light distribution is so loosely defined (per draft 3) that it can vary in a substantially uncontrolled manner. For example an LED light bulb represented by plot 'B' in the graph above is not an appropriate substitute for the "general service lamp" as the term is contemplated in the **"Energy Independence and Security Act of 2007"**.

### Proposed Change Contradicts the DOE's Own Research

The DOE Office of Energy Efficiency and Renewable Energy itself funded research in the 1990's on the effect of differences in omnidirectional bulb light distributions on overall performance. The research was conducted by the Lighting Systems Research Group of the Buildings and Technology Program of the Energy and Environment Division of the Lawrence Berkley National Lab. This research was reported in Erik Page et al. "A Comparative Candle Power Distribution Analysis for Compact Fluorescent Table Lamp Systems", 1995 and in Erik Page et al., "Integral CFLs Performance in Table Lamps", 1997. While this research was conducted in the context of CFL lamps the focus of the research is on what distribution of light

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<sup>7</sup> See <http://www.lightingprize.org/pdfs/LPrize-Revision1.pdf>, page 4, 60 watt incandescent lamp replacement.

<sup>8</sup> Draft-1, draft-2, and draft-3 are available at [http://www.energystar.gov/index.cfm?c=new\\_specs.integral\\_leds](http://www.energystar.gov/index.cfm?c=new_specs.integral_leds)

<sup>9</sup> See "Energy Independence and Security Act of 2007", Title III, Subtitle B-"Lighting Energy Efficiency", Section 321 (a) 6 (A) and Section 321 (a)(1)(BB)(i)(III)

is best for omnidirectional light bulbs. Therefore the conclusions of this research are equally applicable to LED based omnidirectional light bulbs.<sup>10</sup>

Both of these papers draw the unequivocal conclusion that omnidirectional light bulbs should provide strong light intensity in the vicinity of zenith (0°, for up lighting through the top of the lamp shade) and nadir (180°, for task illumination around the lamp). Draft 3 has removed the requirement for light in the vicinity of zenith that was in draft 2 and does not establish any requirement for light in the vicinity of nadir. (The 20% required light in the polar angle range 90° to 180° is permitted to be, and based on designs currently being offered by low cost manufactures likely would be substantially confined to a small angular range in the vicinity of 90°, far away from nadir)

Some quotes from these DOE research papers are relevant to what standards should be established for omnidirectional LED integral lamps. In discussing the impact of table lamps and floor lamps on energy consumption the researches state in the 1995 paper:

*“A significant portion of these high use sockets are table or floor lamps”*

In discussing consumer expectations regarding such lamps the paper states:

*“Consumers are used to a bright halo of light emanating from the top aperture of the shade and bright illumination directly below the shade for high-definition tasks such as reading.”*

Most relevant to the ill-advised proposed slackening of the uniformity requirements for LED omnidirectional lamps that is contained in Draft-2, the researcher’s state:

*“A comparison of the A-lamp and the circline demonstrates the advantage of focusing output vertically.”* {emphasis added, vertically means near nadir and zenith}

*“While the A-lamp yields the largest total lumen package of 1815 lumens, the circline has a much more intense output at the crucial nadir and zenith angles. In effect, fewer total lumens are required to produce sufficient illumination where it is actually needed: at nadir for task lighting and zenith for indirect lighting”* {emphasis added}

In the abstract of the 1997 written after more extensive research the researchers state:

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<sup>10</sup> (By far the most significant omnidirectional light bulb, in terms of energy use is the common household light bulb)

*"It is our assertion that the lumen distribution of the light source within the luminaires plays a critical role in total light output, fixture efficiency and efficacy, and, perhaps most importantly, perceived brightness." {per draft 3 the requirements on the distribution all but non-existent}*

On page 4 the 1997 DOE paper states:

*"The most critical angles are those below the shade (Figure 1, 0° to 60°)<sup>11</sup> because the light output from this area illuminates the task plane."*

*"The results displayed in Figure 1 agree with our hypothesis. We can see that the globe and horizontal sources generate more light than verticals at near zenith angles, the horizontal sources yield the most light at nadir angles, and all three sources yield similar output in the shade region."*

and

*"The horizontal sources yield significantly more light out the bottom aperture of the shade. They concentrate their illumination vertically and most extend radially out around the center of the fixture circumventing light blockage due to the fixture base."*

**In conflict with the DOE's own research which drew the definite conclusions that it is important to provide adequate light in the vicinity of nadir and zenith, the DOE draft-3 requirements for omnidirectional LED lamps has almost no requirements on the light distribution, i.e., the only requirement is that 20% of the light fall somewhere within 90° to 180°.**

### Technical Feasibility Of Meeting Better, More Stringent Proposed Standard

The more stringent uniformity requirement that I am suggesting: +/- 10% over the entire 0-180° can be met. For example, my own pending patent application PCT US2009/000244 provides an omnidirectional LED light bulb that is superior in both thermal and

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<sup>11</sup> Note that 0 degrees in the coordinate system used in this paper corresponds to 180 degrees in the proposed draft 3 standard, so the 0 to 60 degree deemed "most critical" in the DOE/LBNL paper corresponds to 120 to 180 degree range of the draft 2 proposed standard.

optical performance to existing (very early stage) A-type LED light bulbs and can meet this more stringent uniformity requirement. My own patent application has been published and has received an entirely positive search report issued by the International Search Authority<sup>12</sup>. Several drawings of the LED light bulb are shown below. Figure 3 is a perspective of the omnidirectional LED bulb.

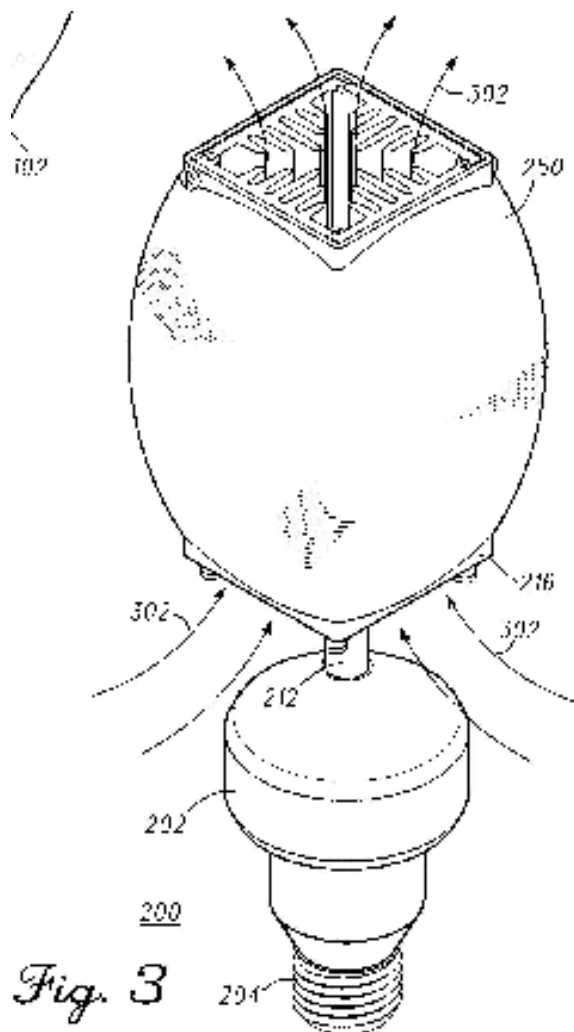
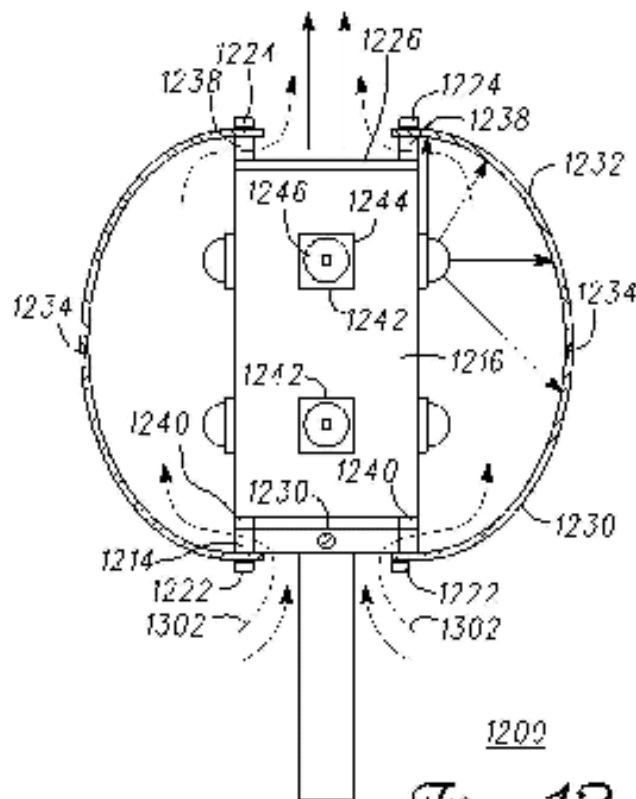


FIG. 13 is partial cross-sectional view through the top of the bulb which illustrates an arrangement of the outer bulb shape diffuser that allows all the light emitted by the LEDs 1244, 1242 to be diffused by the diffuser while allowing natural convection air flows to flow through and around the central heat sink. The overall thermal resistance of the bulb is much better than existing LED bulbs and can handle 10 watts of LED input power while maintaining the LEDs well within manufacture recommended temperature limits.

<sup>12</sup> The published patent application and results of the search can be viewed at <http://www.wipo.int/pctdb/en/wo.jsp?WO=2009091562> under the documents tab.



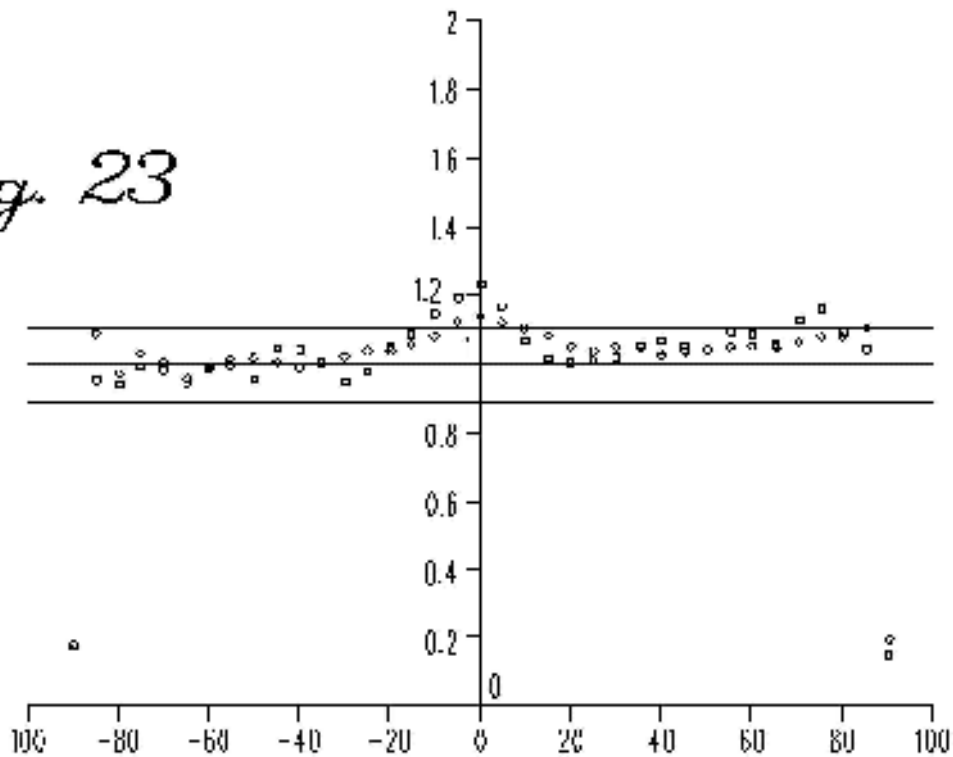


1200  
*Fig. 13*

By providing the LEDs with specially designed (patent pending<sup>13</sup>) lenses, each LED can be made to emit nearly uniformly over a hemisphere ( $2\pi$  Steradian). The near uniformity is shown in the graph below with intensity represented by diamond symbol data points plotted against polar angle. (It is expected that even more uniform lens could be produced with a couple of design iterations made on higher precision equipment than was available, BUT these lenses are sufficient, when used with a diffusive bulb-shaped cover 1232, 1230, to meet the more stringent standard proposed herein.)

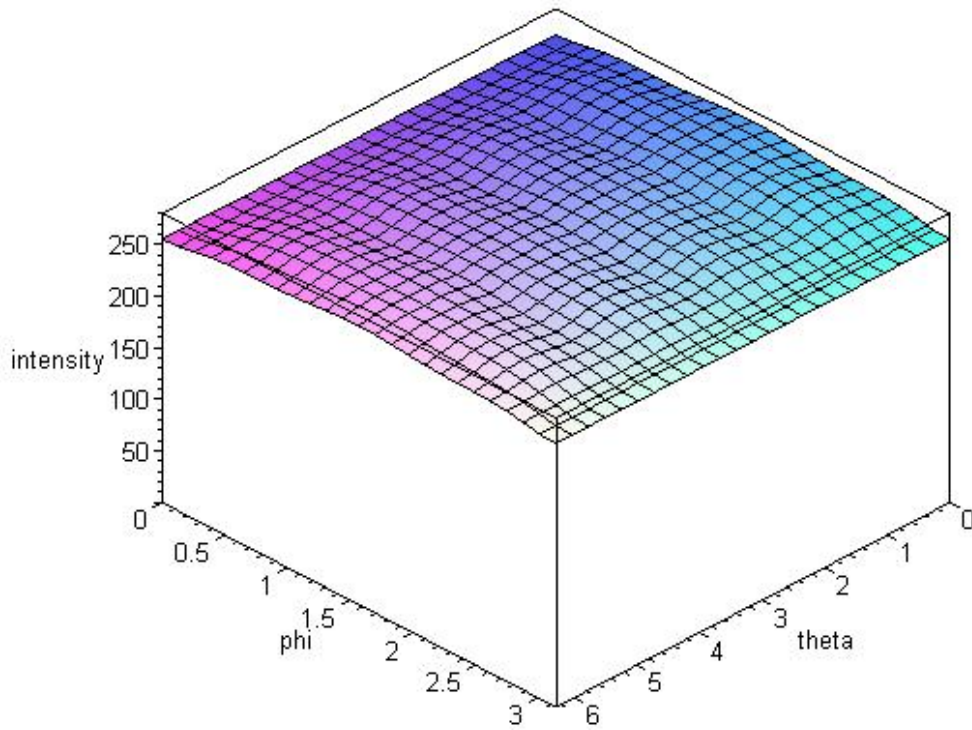
<sup>13</sup> Described on pages 16-25 of published patent <http://www.wipo.int/pctdb/en/wo.jsp?WO=2009091562>, documents tab.

*Fig. 23*



By arranging the LEDs in the bulb facing in all four cardinal directions, each pair of LEDs facing in opposite directions (e.g., N & S) will nearly cover the complete sphere of solid angle,  $4\pi$  steradian, around the bulb. The two pairs together (e.g., N & S and E & W) will cover the  $4\pi$  steradian twice over. Light from different LEDs combines together generally smoothing out the small ripples in light intensity shown in FIG. 23. The bulb shaped diffusive cover (250, 1230, 1232 in FIGs. 3, 13) further smoothes the ripples in intensity. The resulting light distribution over  $4\pi$  Steradian is quite uniform as shown in FIG. 4 below. The maximum intensity is 8% higher than the minimum so that the originally proposed (Draft-1) uniformity specification of  $\pm 10\%$  relative to the mean can easily be met and the same standard can be met over the wider proposed 0-180° range.

FIG. 4.



Additionally, it has recently be announced that Philips Lighting has developed a light bulb design that is purported to meet the +/-10% over 0°-150° L-Prize uniformity criteria.

#### Recommended Standard

I believe that it is of the utmost importance that the DOE reverse course and adapt a uniformity standard that is (1) consistent with its own research, (2) consistent with the L-prize criteria, and (3) consistent with the predominant use of omnidirectional LED light bulbs as “General Service Lamps” addressed in “***Energy Independence and Security Act of 2007***”. At a minimum the DOE should return to the draft-1 standard, i.e., +/- 10% over 0° to 150°. It would be fully consistent with the conclusions of the DOE research to extend the angular range to 180°.

Cordially,  
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